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RESEARCH MEMORANDUM

PRELIMINARY INVESTIGATION AT A MACH NUMBER OF 1.9 AND A REYNOLDS NUMBER OF 2,200,000 OF THREE AILERONS APPLICABLE TO THE BELL XS-2 AIRPLANE DESIGN

By

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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PRELIMINARY INVESTIGATION AT A MACH NUMBER OF 1.9 AND A REYNOLDS NUMBER OF 2,200,000 OF THREE AILERONS APPLICABLE TO THE BELL XS-2 AIRPLANE DESIGN

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SUMMARY

A 42.7° sweptback tapered wing with three types of ailerons was tested in the Langley 9- by 12-inch supersonic blowdown tunnel at a Mach number of 1.9 and a Reynolds number of 2,200,000. The wing geometry was essentially that of the XS-2 airplane. One of the ailerons had the basic airfoil contour which was an 8-percent-thick symmetrical biconvex section with a trailing-edge angle of 19.8° as measured in the free-stream direction. The second aileron had the basic plan form but was cusped to have a 7.4° trailing-edge angle. The third aileron also had a 7.4° trailing-edge angle which in this case was obtained by extending the aileron chord to twice that of the basic aileron.

The basic and cusped ailerons had essentially the same effectiveness although the effectiveness of the basic aileron tended to level off at deflections above 9°. The extended chord aileron had almost twice the effectiveness as the other two ailerons. The effectiveness of all three ailerons varied approximately linearly with aileron deflection. For angles of attack up to 4°, the highest tested, the aileron effectiveness was independent of angle of attack.

INTRODUCTION

Recent preliminary free-flight tests of rocket-propelled vehicles have indicated that the airfoil section of a sweptback wing may have an appreciable effect on the aileron rolling effectiveness at high subsonic, transonic, and supersonic speeds. The effect of airfoil section may be due to the trailing-edge angle inasmuch as the aileron effectiveness decreased with increasing trailing-edge angle and, in some cases, reversed over part of the speed range. The biconvex airfoil section incorporated in the wing design of the XS-2 airplane has a relatively large trailing-edge angle. The aileron characteristics of such an airplane may, therefore, be undesirable.

In order to investigate the effectiveness of ailerons at a Mach number of 1.9, a 42.7° sweptback tapered wing of essentially the same geometry as the XS-2 wing was tested in the Langley 9- by 12-inch supersonic blowdown tunnel. This tunnel operates from the exhaust of the Langley 19-foot pressure tunnel. Reported herein are the preliminary results of this investigation which included tests with an aileron having the basic airfoil contour with a trailing-edge angle of 19.8° in the free-stream direction and with each of two ailerons having a trailing-edge angle of 7.4°. One of the latter ailerons had the basic aileron plan form but had a cusped trailing edge. The other aileron had chords which were twice the basic aileron chords and had flat sides.

SYMBOLS

C_L lift coefficient

C_D drag coefficient

C_m pitching-moment coefficient based upon mean aerodynamic chord and computed about a line normal to the plane of symmetry and passing through the quarter-chord point of the mean aerodynamic chord

C_l rolling-moment coefficient

δ_{a_L} deflection of left-wing aileron in plane perpendicular to hinge line, positive when trailing edge is deflected downward

α angle of attack

M Mach number

R Reynolds number based upon mean aerodynamic chord

c wing chord in free-stream direction

MODEL AND TESTS

The geometry of the semispan wing is shown in figure 1. The wing contour was formed in a lathe so that each wing surface is a section of a cone. The wing-chord plane, if extended, would pass through the cone apex. The wing has an aspect ratio of 4, taper ratio of 0.5, and a thickness ratio of 10 percent measured in a plane perpendicular to the quarter-chord line of the swept-wing panel. The airfoil section perpendicular to the chord plane is a segment of an ellipse but very

closely approximates the ordinates of a circular-arc section. Table I gives the ordinates of the airfoil section parallel to the air stream. Manufacturing accuracy for the surface contour is ±0.002 inch. As measured parallel to the air stream, the included angle at the airfoil leading edge is practically identical to that of a circular-arc airfoil while the trailing-edge angle is 19.8° as compared with 20.0° for the circular-arc section.

The three ailerons tested on this wing are shown in figure 1. All ailerons are hinged at the 80-percent-chord line as measured in the free-stream direction and the hinge axis lies in the chord plane. The contours of aileron 1 follow the basic contours of the wing. Aileron 2 has the same plan form as aileron 1 but has a cusp-shape trailing edge, with the trailing-edge angle greatly reduced. Aileron 3 has twice the chord of the first two ailerons and has straight-sided upper and lower surfaces. It has the same trailing-edge angle as aileron 2.

The wing was tested with the ailerons deflected approximately 0°, 2°, 4°, 6°, 9°, and 15° measured in a plane perpendicular to the hinge line. The deflections were in one direction only, positive if the model is considered to be a right-hand panel of a complete wing or negative if considered to be a left-hand panel. By testing the model with symmetrical airfoil sections through an angle-of-attack range from -4° to 4°, data were obtained which would apply to a complete wing with the left aileron deflected both positively and negatively.

TUNNEL AND TEST TECHNIQUE

The Langley 9- by 12-inch supersonic blowdown tunnel in which the present tests were made is a nonreturn-type tunnel utilizing the exhaust air of the Langley 19-foot pressure tunnel. The inlet air which enters at an absolute pressure of about $2\frac{1}{3}$ atmospheres contains about 0.003 pound of water per pound of air. Free-stream Mach number is 1.90.

The semispan model is cantilevered from the tunnel wall and is attached to a four-component balance. The balance rotates with the model as the angle of attack is changed and measures pitching moment, chord force, normal force, and rolling moment due to normal force. The errors in computing rolling-moment coefficient from only the normal-force component are believed negligible because of the small range of angles of attack. The wing root operates in a region of reduced flow and surveys indicate that free-stream Mach number is reached 0.4 inch out from the tunnel wall. Because of the large size of the model compared with the boundary layer and because of the location of the aileron, the wall boundary layer should have little effect on the increments in the aerodynamic forces caused by aileron deflection.

The wing is attached to a 4-inch-diameter disk which is flush with the tunnel wall and which rotates with the model. Gaps around this disk are small and the balance chamber is sealed. Calibration tests indicate no noticeable effect of air flow in and around this disk.

The dynamic pressure and test Reynolds number decreased less than 5 percent during the course of each run because of the decreasing pressure of the inlet air. The average dynamic pressure for these tests was 1670 pounds per square foot and the average Reynolds number was 2,200,000.

PRECISION OF DATA

Free-stream Mach number has been calibrated at 1.90 ± 0.02. This Mach number was used in determining the dynamic pressure and no account has been taken of the decreased dynamic pressure in the tunnel-wall boundary layer. Only a comparative analysis, therefore, should be made from these data. It is believed that no large errors exist, however, since the measured lift-curve slope of 0.040 for these tests agrees reasonably well with the theoretical lift-curve slope of 0.043 for this wing.

The accuracy of measurements is indicated in the following table:

Variable	Error
α	$\pm 0.05^{\circ}$
δ_{a_L}	$.2^{\circ}$
C_L	.005
C_l	.0003
C_m	.001
C_D	.001

The listed errors apply only for low aileron deflections. Above about 5° aileron deflection, C_l, C_m, and C_D showed unsteady variations with resulting errors of about twice those indicated in the table for these components.

RESULTS AND DISCUSSION

All data have been reduced to standard nondimensional coefficients and the results shown in figures 2 and 3 apply to a complete wing with the left aileron deflected while those shown in figure 4 apply to a complete wing with both ailerons deflected in the same direction. The measured rolling-moment coefficients of the semispan model were plotted against angle of attack and the increments in rolling-moment coefficient due to aileron deflection were obtained from faired curves. Within the limits of accuracy of the data, these increments, plotted in figure 2, were independent of the angle of attack.

Aileron Effectiveness

The effectiveness of the three types of ailerons tested on the 42.7° sweptback tapered wing is shown in figure 2 for angles of attack of 0° to 4°. The basic and cusped ailerons were equally effective over most of the deflection range but the effectiveness of the basic aileron showed a tendency to level off for deflections above 9°. The extended-chord aileron was almost twice as effective as either of the other two ailerons.

The damping coefficient in roll for a wing of this plan form at a Mach number of 1.9 has been calculated to be -0.31 by means of linearized supersonic wing theory. Using this value, it is estimated that the wing-tip helix angle generated by a wing with the basic ailerons deflected ±5° would be 0.011 radian or 0.0022 radian per degree aileron deflection, and with the basic ailerons deflected ±10° it would be 0.021 radian or 0.0021 radian per degree aileron deflection. These values are about 20 percent higher than those obtained in free-flight rocket tests of a comparable configuration.

Aerodynamic Characteristics

The aerodynamic characteristics of the 42.7° sweptback tapered wing are shown in figure 3 as a function of angle of attack and in figure 4 as a function of aileron deflection for each of the three types of ailerons. As mentioned previously the data in figure 4 would apply to a complete wing with both left and right ailerons deflected in the same direction. With zero aileron deflection (fig. 3) the lift, drag, and pitching-moment coefficients are all increased in magnitude by the extended-chord aileron. This increase is mainly due to the increment in area added by the extended-chord aileron since the basic wing area was used in computing the coefficients. As shown in figure 4, deflecting the extended-chord aileron produced about twice the increment in lift and pitching moment as did the basic or cusped ailerons.

It is also of interest to note that, from the rolling-moment measurements at zero aileron deflection (not shown herein), the spanwise center of pressure was at 45 percent of the semispan; this position is very close to the spanwise position of the center of area.

CONCLUSIONS

From tests at a Mach number of 1.9 of a 42.7° sweptback tapered wing with three types of ailerons in the Langley 9- by 12-inch supersonic blowdown tunnel, the following conclusions may be drawn:

1. Reducing the trailing-edge angle of the aileron from 19.8° for the basic airfoil contour to 7.4° by cusping the aileron contour had very little effect upon the aileron effectiveness.

2. Extending the aileron chord to twice the basic aileron chord approximately doubled the aileron effectiveness.

3. The effectiveness of all three types of ailerons varied approximately linearly with aileron deflection although the effectiveness of the basic aileron showed a tendency to level off for deflections above 9°.

4. For angles of attack up to 4°, the highest tested, the aileron effectiveness was independent of angle of attack.

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TABLE I

ORDINATES FOR AIRFOIL SECTION OF 42.7° SWEPTBACK TAPERED WING

[Stations and ordinates given in percent airfoil chord in free-stream direction; section symmetrical about chord line]

Station	Ordinate
0	0
5	.712
10	1.357
15	1.935
20	2.444
25	2.884
30	3.253
35	3.549
40	3.772
45	3.919
50	3.989
55	3.981
60	3.892
65	3.720
70	3.463
75	3.120
80	2.686
85	2.161
90	1.540
95	.821
100	0

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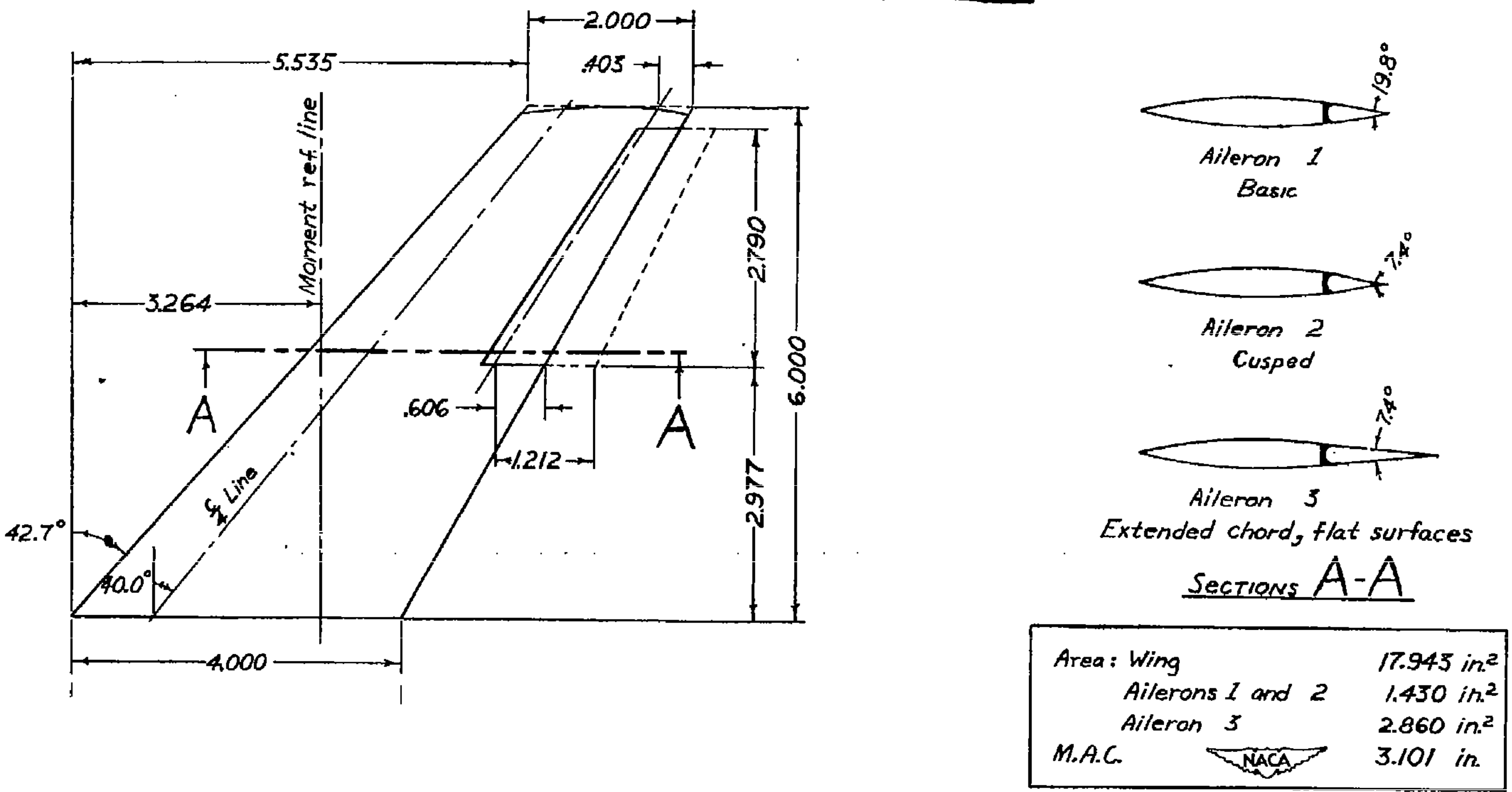

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Figure 1.- Details of 42.7° sweptback wing and ailerons. (All dimensions in inches.)

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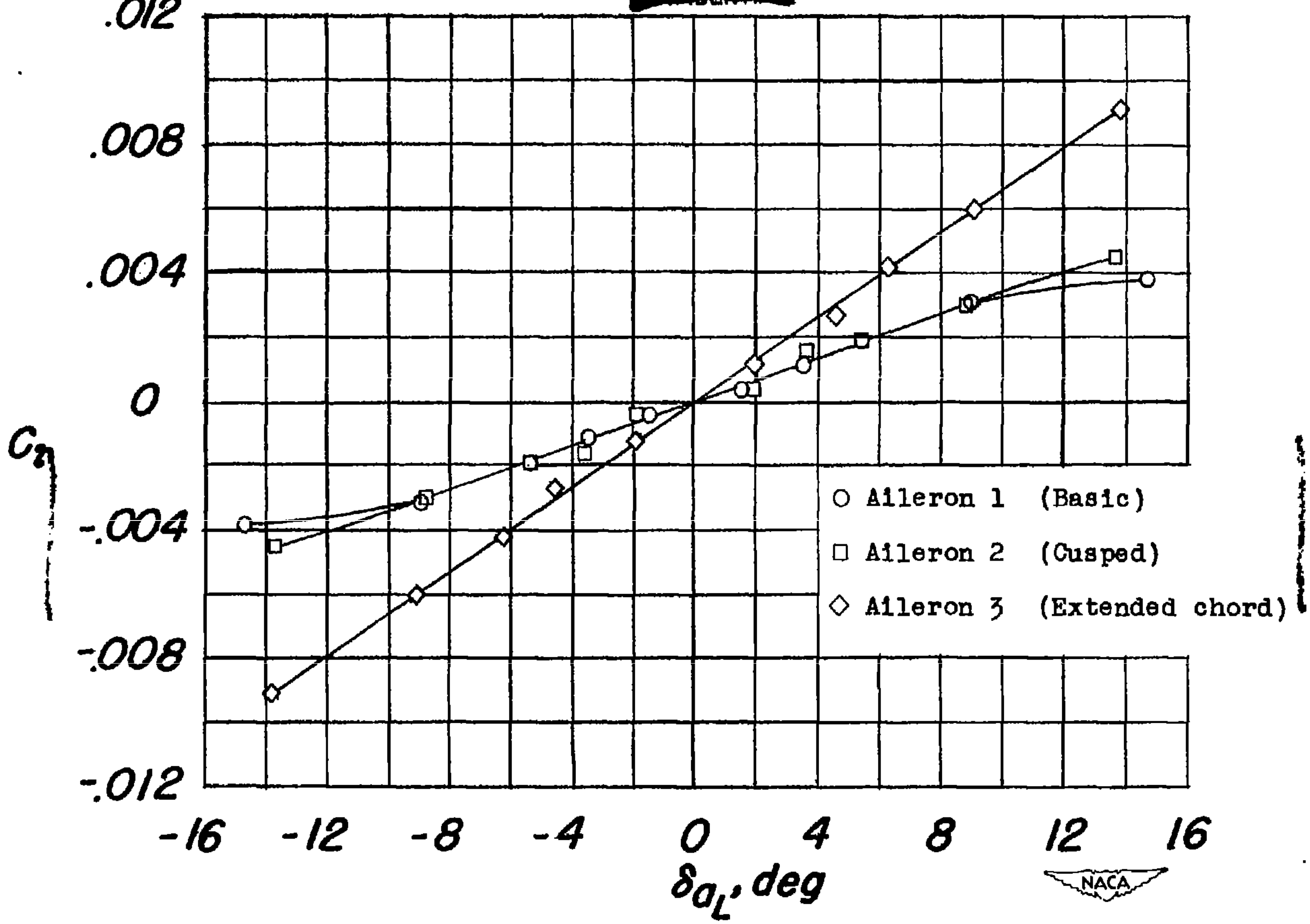

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Figure 2.- Effectiveness of three types of ailerons on 42.7° sweptback tapered wing; $\alpha = 0^{\circ}$ to 4°; $M = 1.9$; $R = 2.2 \times 10^{6}$.

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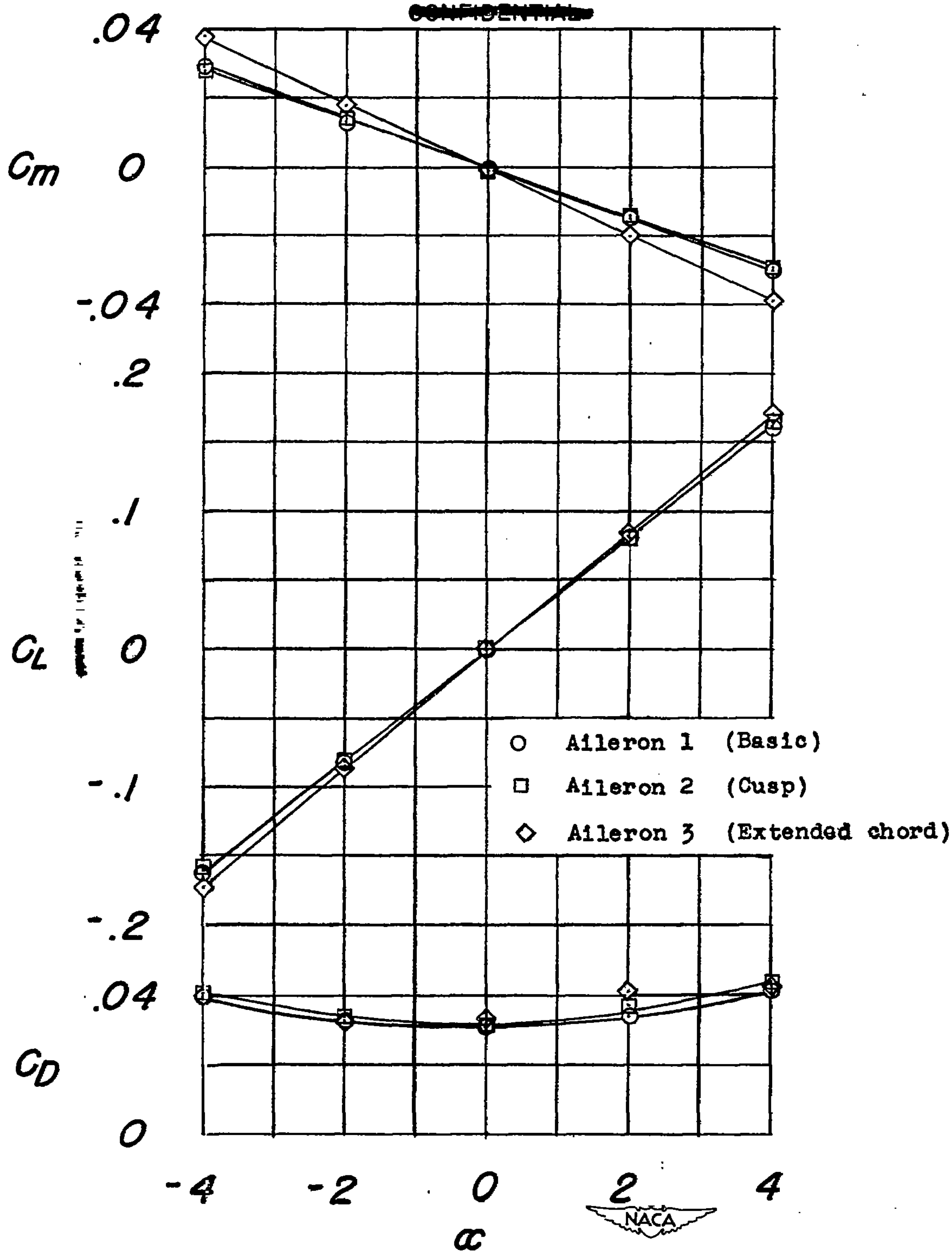

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Figure 3.- Aerodynamic characteristics of a 42.7° sweptback tapered wing with three types of ailerons; $\delta_{a_L} = 0^{\circ}$, $M = 1.9$, $R = 2.2 \times 10^{6}$.

[redacted]

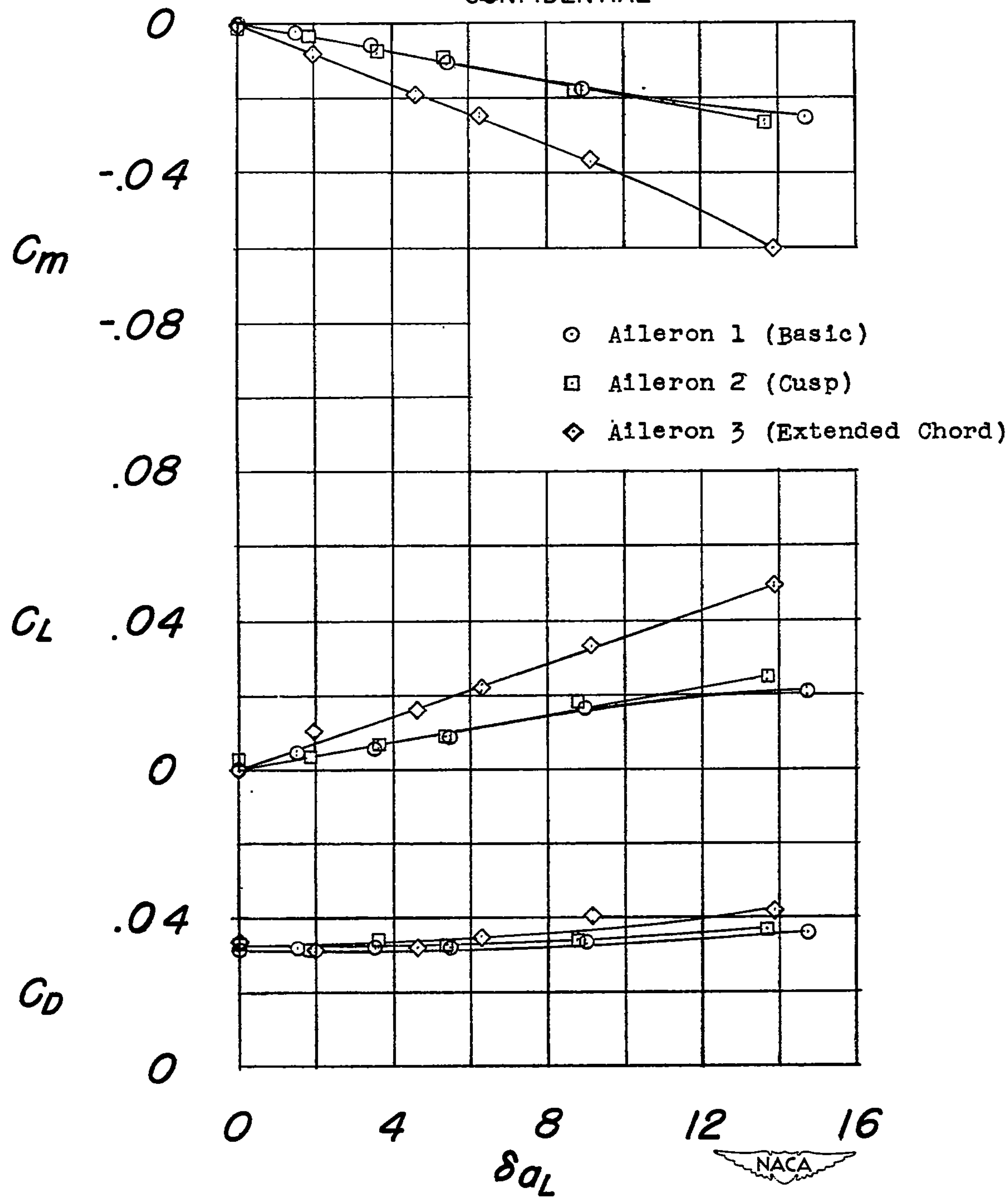

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Figure 4.- Aerodynamic characteristics of a 42.7° sweptback tapered semispan wing with each of three types of ailerons deflected; $\alpha = 0^\circ$, $M = 1.9$, $R = 2.2 \times 10^6$.